ONE-DIMENSIONAL SIMULATION OF A DIESEL ENGINE OPERATING WITH BIODIESEL

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I certify that the project entitled *"One-dimensional Simulation of a Diesel Engine Operating with Biodiesel"* is written by *Mohd Rizal Bin Shafie*. I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

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Examiner	Signature

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This study is to explore one-dimensional simulation for four cylinders diesel engine. The simulation and computational development of modelling for the research is used the commercial Computational Fluid Dynamics (CFD) of GT-SUITE 6.1 software. The engine model was developed corresponding to a 2.0 litre Mitsubishi 4D68 four-cylinder diesel engine. The diesel engine is simulated to study the characteristic of engine performance when the engine is operating with biodiesel as an alternative fuel. The development of one-dimensional simulation modelling covers full engine cycle consisting of intake, compression, power and exhaust system. For the fuel used which is biodiesel, the database of biodiesel need to be determined because there is no available database for one-dimensional simulation. The results obtained from simulation were compared with the data from the diesel engine operating with conventional diesel. Then, the results gained for biodiesel simulation is compared to experiment to gain more information about its trend. The simulation results showed that the brake power and brake torque were reduced if the diesel engine was being fuelled with biodiesel. Using biodiesel also decrease brake thermal efficiency. The decrease of low heating value resulted to increase brake specific fuel consumption.

ABSTRAK

Kajian ini bertujuan untuk mengkaji simulasi satu dimensi bagi enjin diesel empat silinder. Simulasi dan pembangunan pengkomputeran model untuk kajian adalah menggunakan perisian komputasi bendalir dinamik (CFD) GT-SUITE 6.1. Model enjin dibangunkan berdasarkan enjin empat silinder Mitsubishi 4D68, 2.0 liter. Enjin diesel ini disimulasikan untuk mengkaji corak prestasi enjin apabila ianya menggunakan biodiesel sebagai bahan bakar alternatifnya. Pembangunan permodelan satu dimensi merangkumi sistem penyedupan, pemampatan, pembakaran dan sistem ekzos. Bahan bakar yang digunakan adalah biodiesel, justeru itu pangkalan data biodiesel perlu dikenalpasti kerana ianya belum ada bagi simulasi satu dimensi. Keputusan simulasi yang diperolehi dibandingkan dengan data dari enjin diesel yang beroperasi menggunakan minyak diesel biasa. Seterusnya, keputusan bagi simulasi biodiesel dibandingkan dengan eksperimen untuk memperolehi lebih maklumat mengenai coraknya. Keputusan simulasi menunjukan kuasa dan daya kilas merosot apabila enjin diesel menggunakan biodiesel sebagai bahan bakarnya. Penggunaan biodiesel juga menurunkan keberkesanan terma. Penurunan nilai pemanasan rendah mengakibatkan penggunaan bahan bakar khusus meningkat.

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LIST OF SYMBOLS

W	Work per cycle
A_p	Piston face area of all pistons
$\overline{U}_p$	Average piston speed
T	Torque
W_b	Brake work of one revolution
V_d	Displacement volume
n	Number of revolutions per cycle
η_{bth}	Brake thermal efficiency
$\dot{m}_f$	Rate of fuel flow into engine
$\dot{W}_b$	Brake power
η_{υ}	Volumetric efficiency

LIST OF ABBREVIATIONS

AFR	Air-fuel ratio
BDC	Bottom dead center
BP	Brake power
BSFC	Brake specific fuel consumption
BT	Brake torque
B5	Biodiesel blend (5 % biodiesel, 95 % petroleum)
B100	Biodiesel blend (100 % biodiesel)
CFD	Computational Fluid Dynamics
CI	Compression ignition
CO	Carbon monoxide
DI	Direct injection
FAEE	Fatty Acid Ethyl Ester
FAME	Fatty-Acid Methyl Ester
HC	Hydrocarbon
MEP	Mean effective pressure
NMHC	Non-Methane Hydrocarbon Compounds
NO_x	Nitrogen Oxide
PM	Particulate matter
POME	Palm Oil Methyl Ester
REE	Rapeseed Ethyl Ester
RME	Rapeseed Methyl Ester
SI	Spark-ignition
SOF	Soluble organic fraction

SO_2	Sulfur
TDC	Top dead center

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

For over centuries, machines are very common in term of helping human kind. For the main observation, transportation is very needed by all human to easier their task, easier their work. As the population grows, vehicles have become the number one in the chart of very important asset compared to other valuable asset. And the heart of this vehicle is engine.

Diesel engines which are direct injection (DI) and compression ignition (CI) engines have dominated the field of heavy-duty vehicles and marine transportations. Diesels are workhorse engines. That is why the diesel engines powering heavy-duty trucks, tractors, ships and other construction equipment. But the diesel engines are very dirty, loud and produce more emission. These superb diesel engines are increasingly being applied to light-duty vehicle in the past 30 years (Zheng, 2009).

Latest and modern diesel engines require more clean burning, stable fuel that will perform well in a numerous of operation varieties (Tsolakis et al., 2007). Therefore with the latest technology, there have been greater improvements toward these engines. However, the increase in price of diesel fuel, the rapid depletion of petroleum fuel and also higher stringent emission regulation force us to search for alternative fuel which can reduce emissions (Chen et al., 2008, Zheng, 2009).

In order to create alternative oxygenated fuels, the vegetable oils or their derived biodiesels (methyl or ethyl esters) are recently considered as promising fuels to supplant the fraction of petroleum distillates. The benefit of biofuel now has become valuable asset for reduction of greenhouse gas emissions (Luján et al., 2009b, Wheals et al., 1999). For diesel engines, biodiesel is under study as a viable alternative fuel for those engines (Luján et al., 2009b). Fuel derived from biological sources showing important advantages in emitted CO_2 reduction (Rickeard and Thompson, 1993, Graboski and McCormick, 1998, Demirbas, 2003). Although CO_2 is a kind of greenhouse gas, the CO_2 released by biofuel combustion can be fixed by growing more plants thus makes no net contribution to global warming (Wheals et al., 1999).

The previous study of diesel engine with biofuels such as biodiesel has promising the bright future especially in automotive industry; as replacement of diesel fuel and environment ecosystem.

1.2 OBJECTIVES

The objectives of this study are to:

i. Perform one-dimensional simulation of a diesel engine operating with biodiesel.
ii. Establish the database of biodiesel in GT-Suite.

1.3 SCOPE OF THE PROJECT

i. Perform one-dimensional engine modeling.
ii. Determine the characteristic of biodiesel (calculation based).
iii. Construct the database of biodiesel in simulation software.

1.4 PROBLEM STATEMENT

1.4.1 Problem

In the simulation software, there is no database of biodiesel available for one-dimensional simulation. It is very important to know the trend for the diesel engine which is being operated with biodiesel fuel.

1.4.2 Solution of The Problem

GT-POWER is a user friendly and very suitable for every engine simulation and being used by most car manufacturers. Therefore there is an alternative for the problem in defining fuel for the simulation. GT-POWER allows the users to create their own fuel files on the specific button to use the pre-processor. Referring to the biodiesel properties table, the biodiesel fuel can be created. The results gain by the simulation can give overview on how the biodiesel affect the diesel engine.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter covers the recent review of diesel engine powered with biodiesel research activities are presented here. All the studies are mainly focus on the performance and emissions characteristic for the diesel engine operating with biodiesel and comparison to conventional diesel engine.

2.2 BASIC INTERNAL COMBUSTION ENGINES

2.2.1 Reciprocating Engines

The reciprocating engine, basically a piston-cylinder device, is one of the rare and creative inventions that have proved to be very versatile. They and have been used in many range of applications. It is the powerhouse of the vast majority trucks, automobiles, ships and electric power generators. (Yunus and Michael, 2007)

Figure 2.1 shows the basic components of a reciprocating engine. The piston reciprocates in the cylinder between two fixed positions called the top dead center (TDC). TDC is the position of the piston when it forms the smallest volume in the cylinder. Besides TDC, the latter position known as bottom dead center (BDC) indicates the position of the piston when it forms the largest volume in the cylinder (Figure 2.2). The stroke of the engine is the distance between the TDC and BDC which it has the largest distance that the piston can travel in one direction. Bore is the diameter of the piston. Intake valve allows the air or air-fuel mixture to be drawn into the cylinder. While the exhaust valve function is to expel the combustion products.

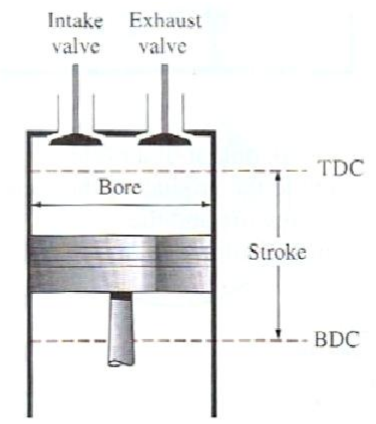

Figure 2.1: Nomenclature of reciprocating engines

Source: Yunus and Michael, 2007

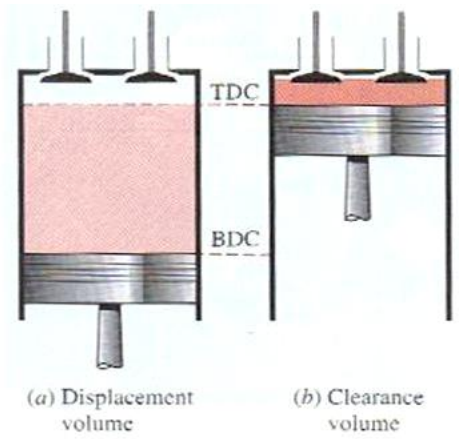

Figure 2.2: Displacement volume and clearance volume of reciprocating engine

Source: Yunus and Michael, 2007

The displacement volume is the term to indicate the volume displaced by the piston as it moves between TDC and BDC. The frequently used term in conjunction with reciprocating engines is the mean effective pressure (MEP). MEP is the fictitious pressure that, if it acted on the piston during the entire power stroke, which can produce the same amount of net work as the produced during the actual cycle. It also can be used as a parameter to compare the performance of reciprocating engine of equal size. The larger of MEP on the engine will deliver more net work per cycle and give better performance (Yunus and Michael, 2007).

The concept of compression ratio is really simple. During the compression process, the collisions between molecules will initiate heat that ignites the diesel fuel (Dempsey, 2008). In Figure 2.3, simple expression on mathematical forms and pictures will explain details.

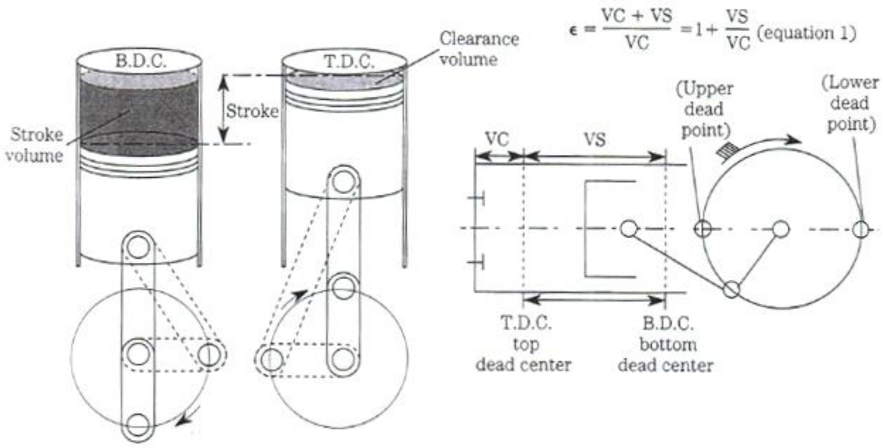

Figure 2.3: Concept of compression ratio

Source: Dempsey, 2008

The reciprocating engines are classified as compression-ignition (CI) engines or spark-ignition (SI) engine. Both of them are depending on how the combustion process in the cylinder is initiated. In CI engines, the air-fuel mixture is self-ignited because of the compressing the mixture above its self-ignition temperature. While in SI engines, the spark plug will initiate the combustion of the air-fuel mixture (Yunus and Michael, 2007).

2.3 DIESEL ENGINES

The history of biodiesel was started by Dr. Rudolf Diesel (1858 to 1913). In 1892, he embarked on research at MAN in Augsburg on his totally new engine which the ignition of fuel by compression process (GmbH, 2004). After many years of exploration and research, he introduced world's first diesel engine. Compared to gasoline engines and steam engines, this engine had number of advantages. It is less fuel consumptions and could be dimensioned for higher power outputs.

In 1922, Robert Bosch decided to develop a fuel-injection system for diesel engines. Those Bosch fuel-injection pumps were a stepping stone in achieving higher running speeds in diesel engine. In 1936, Mercedes-Benz 260D (2580 cc, 50 hp) was the first volume-production car to be fitted with a diesel engine. The vision of Rudolf Diesel had become reality. (GmbH, 2004)

The diesel engines are compression-ignition (CI) engines. In diesel engines, the spark plug and carburetor are replaced by a fuel injector. This due to the air when being compressed to a temperature that is above the auto-ignition temperature of the fuel, and combustion creates on contact as the fuel is injected into this hot air. In spark-ignition (SI) engines, also known as gasoline engines, air-fuel mixture is compressed during the compression stroke and the compression ratios are limited by the onset of auto-ignition or engine knock. But in diesel engines, only air is compressed during the compression stroke, which can eliminate the possibility of auto-ignition. (Yunus and Michael, 2007)

Therefore the diesel engines can operate on much higher compression ratios, between 12 and 24. Besides that, many of the stringent requirements placed on the gasoline engine can be removed from diesel engine. Thus less refined fuels (less expensive fuel) can be used in diesel engine. The diesel engines also burn fuel more completely compared to gasoline engines since they work on lower revolutions per minute (rpm) and having higher air-fuel mass ratio. It is more efficient than spark-ignition engine (gasoline) because they operate at much higher compression ratios (Yunus and Michael, 2007). Lower fuel cost and higher efficiency become the reason why they have been used in large ships and emergency power generation units. Figure